CHM129

Manipulations of the Equilibrium Constant

1. Predict the equilibrium constant for:

$CO_{2\,(g)} + 3\ H_{2\,(g)} \leftrightarrow CH_3OH_{\,(g)} + H_2O_{\,(g)}$ **$K_1 = ?$**

given the equilibrium constants for the following reactions.

$CO_{\,(g)} + H_2O_{\,(g)} \leftrightarrow CO_{2\,(g)} + H_{2\,(g)}$ $K_2 = 1.0 \times 10^5$

$CO_{\,(g)} + 2\ H_{2\,(g)} \leftrightarrow CH_3OH_{\,(g)}$ $K_3 = 1.4 \times 10^7$

$CO_{2(g)} + H_{2(g)} \rightleftharpoons CO_{(g)} + H_2O_{(g)}$ $K = \frac{1}{1.0 \times 10^5}$

$CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$ $K = 1.4 \times 10^7$

$CO_{2(g)} + 3\ H_{2(g)} \rightleftharpoons CH_3OH_{(g)} + H_2O_{(g)}$

$K = \left(\frac{1}{1.0 \times 10^5}\right)(1.4 \times 10^7) = 140$

2. Consider the following chemical equation and equilibrium constant at 25 °C.

$2\ COF_{2\,(g)} \leftrightarrow CO_{2\,(g)} + CF_{4\,(g)}$ $K_c = 2.2 \times 10^6$

Compute the equilibrium constant for the following reaction at 25°C.

$2\ CO_{2\,(g)} + 2\ CF_{4\,(g)} \leftrightarrow 4\ COF_{2\,(g)}$ **$K' = ?$**

$CO_{2(g)} + CF_{4(g)} \rightleftharpoons 2COF_{2(g)}$ $K = \frac{1}{2.2 \times 10^6}$

$2CO_{2(g)} + 2CF_4 \rightleftharpoons 4COF_{2(g)}$

$K = \left(\frac{1}{2.2 \times 10^6}\right)^2 = 2.1 \times 10^{-13}$

3. Find K_c for the following reaction:

$$N_{2\,(g)} + O_{2\,(g)} + Br_{2\,(g)} \leftrightarrow 2NOBr_{\,(g)} \qquad K_c = ?$$

Use the following data to find K_c:

$2NO_{(g)} \leftrightarrow N_{2(g)} + O_{2(g)} \quad K_c = 2.1 \times 10^{30}$

$NO_{(g)} + \frac{1}{2}Br_{2(g)} \leftrightarrow NOBr \quad K_c = 1.41$

$$N_{2(g)} + O_{2(g)} \rightleftharpoons 2\,NO_{(g)} \qquad K = \frac{1}{2.1 \times 10^{30}}$$

$$2\left(NO_{(g)} + \tfrac{1}{2}Br_{2(g)} \rightleftharpoons NOBr_{(g)}\right) \qquad K = (1.41)^2$$

$$N_{2(g)} + O_{2(g)} + Br_{2(g)} \rightleftharpoons 2\,NOBr_{(g)}$$

$$K = \left(\frac{1}{2.1 \times 10^{30}}\right)(1.41)^2 = 9.5 \times 10^{-31}$$

CHM129

The Equilibrium Constant

1. Consider the following reaction:

$$2\ CH_4\ (g) \leftrightarrow 3\ H_2\ (g) + C_2H_2\ (g)$$

A mixture at 1700 °C initially contains $[CH_4]=0.115M$. At equilibrium, the concentration of C_2H_2 is 0.035M. What is the value of the equilibrium constant?

$$K = \frac{[C_2H_2][H_2]^3}{[CH_4]^2}$$

	$[CH_4]$	$[H_2]$	$[C_2H_2]$
I	0.115	0	0
C	−0.070	+0.105	+0.035
E	0.045	0.105	0.035

$$K = \frac{(0.035)(0.105)^3}{(0.045)^2}$$

$$K = 0.020$$

2. Consider the following reaction and its equilibrium constant:

$$I_2\ (g) + Cl_2\ (g) \leftrightarrow 2\ ICl\ (g) \quad K=81.9$$

A reaction mixture contains $[I_2]=0.114M$, $[Cl_2]=0.102M$ and $[ICl]=0.355M$. Is the reaction mixture at equilibrium? If not, in which direction will the reaction proceed?

$$Q = \frac{[ICl]^2}{[I_2][Cl_2]} = \frac{(0.355)^2}{(0.114)(0.102)} = 10.8$$

$Q < K$ Rx runs right (toward products)

3. Consider the following reaction:

$$N_{2\,(g)} + O_{2\,(g)} \leftrightarrow 2\,NO_{(g)} \quad K=0.10 \text{ at } 2000\ ^\circ C$$

A reaction mixture initially contains $[N_2]=0.200M$ and $[O_2]=0.200M$. Find the concentration of the reactants and the products at equilibrium.

	$[N_2]$	$[O_2]$	$[NO]$
I	0.200	0.200	0
C	$-x$	$-x$	$+2x$
E	$0.200-x$	$0.200-x$	$2x$

$$K = \frac{[NO]^2}{[N_2][O_2]} = 0.10$$

$$\frac{(2x)^2}{(0.200-x)(0.200-x)} = 0.10$$

$$\sqrt{\frac{(2x)^2}{(0.200-x)^2}} = \sqrt{0.10}$$

$$\frac{2x}{0.200-x} = \sqrt{0.10}$$

$$2x = (0.200-x)\sqrt{0.10}$$

$$2x = (0.200)(\sqrt{0.10}) - \sqrt{0.10}\,x$$

$$0.063 = 2.3x$$

$$x = 0.027\ M$$

$[N_2]=[O_2] = 0.200M - x$

$= 0.200M - 0.027M$

$= \underline{0.173\ M}$

$[NO] = 2x$

$= 2(0.027M) = \underline{0.054M}$